TITLE: Investigation of a Pulsed Positive Corona in Multipoint-to-Plane Configuration

Investigation of a pulsed positive corona in multipoint-to-plane configuration

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A pulsed corona discharge of positive polarity, in multipoint-to-plane configuration was studied. The distance between pins was optimised for obtaining maximum discharge current at a given voltage. At constant voltage the frequency and amplitude of the current pulses are controlled by a self-triggered spark-gap switch.

1. Introduction

Corona discharges are non-thermal, chemically active plasmas, which receive considerable attention both in connection to their numerous applications [1], and also from a theoretical point of view [2,3].

The present investigation of a pulsed positive corona in multipoint-to-plane configuration is concentrated especially on the influence of the geometry and electrical circuit on the discharge characteristics.

2. Experimental arrangement

The experimental arrangement is shown in Fig. 1. In a cylindrical discharge chamber, the high voltage electrode, consisting in an array of tungsten pins, with 100 μm tip diameter, is placed at approximately 40 mm above a grounded circular grid.

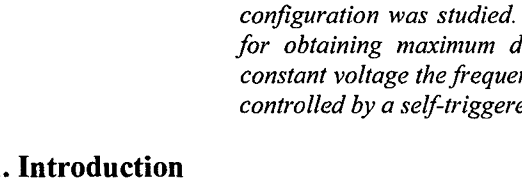

Fig. 1. Experimental set-up

The voltage generator supplies up to 30 kV, charging the capacitor C = 1 nF, which is discharged by means of a self-triggered spark-gap switch (SG). The discharge voltage was measured by a high voltage probe (Tektronix P6015, $R_p = 100$ MΩ) and the discharge current was determined from the voltage fall on a 50 Ω resistor in series with the grid electrode. The voltage and current waveforms are monitored by an oscilloscope (Tektronix TDS 320). The radiation emitted by the plasma is collected by an optical fiber and monitored with a photomultiplier.

The experiments were performed at atmospheric pressure; a fan was used to produce a continuous flow of air through the discharge chamber.

3. Results and discussion

3.1. Single point to plate configuration

Typical voltage and current waveforms are shown in Fig. 2, for a single pin as high voltage electrode, at 24 and 28 kV applied voltage.

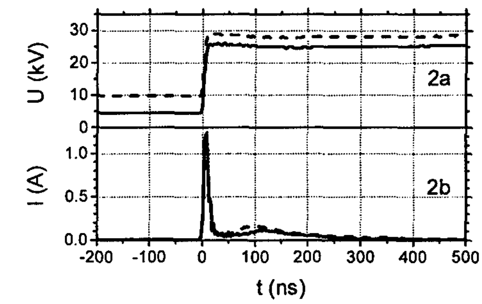

Fig. 2. Typical voltage (2a) and current (2b) waveforms

The rise time of the voltage (10 to 90%) is 7-8 ns, and the voltage rise rate is approximately 2 kV/ns.

The first current peak is a displacement current, which charges the capacitance of the electrode system. This total geometrical capacitance, determined by fitting the calculated dV/dt to the first current peak, is ~1 pF.

The real discharge current is the second, smaller peak, which is confirmed by the temporal correspondence with the radiation emitted from the plasma.

Increasing the applied voltage leads to an increase in current and to a decrease of the time interval between the displacement current and the discharge current. This time interval is connected to the inception probability, which is higher for higher applied electric fields [4]. An increase of the voltage leads also to higher repetition frequency of the pulses, from 450 Hz at 24 kV to 900 Hz at 28 kV. The frequency is controlled in addition by the spark-gap switch operation.

3.2. Influence of the number and position of pins

Adding a second pin leads to an increase of the discharge current. However, if the pins are placed very close to each other, the current remains similar to the value for a single pin. This behavior is most likely due to interactions of the electric fields near adjacent pins. Simulations of pulsed corona in wire-plate configuration [5,6] predict also interference effects on the electric field distributions near neighboring wires, consisting in the reduction of the electron density and electric field in the streamer head, as the spacing between wires decreases.

In the present experiments, the distance between the two pins was varied from 3 to 24 mm. At constant applied voltage (28 kV), the current increases linearly from 190 to 280 mA when increasing the spacing between pins from 3 to 10 mm, and remains around 250 mA for distances longer than 10 mm.

Fig. 3 shows the discharge current as a function of the number of pins, at 28 kV applied voltage and a distance between adjacent pins of 10 mm.

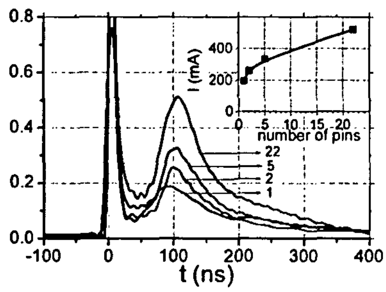

Fig. 3. Discharge current vs. the number of pins

The current is higher as the number of pins increases, reaching more than 500 mA for an array of 22 pins. The maximum number of pins used was limited by the dimensions of the discharge chamber and the optimum spacing between pins. Therefore, in the following experiments this array of 22 parallel pins, placed at 10 mm from each other was used as high voltage electrode.

3.3. Influence of the gap length of the switch

Fig. 4 shows the discharge current waveforms at constant applied voltage (28 kV) for three values of the gap length of the spark-gap switch: d_{SG} = 3,5 and 7 mm, and also the average current as a function of voltage.

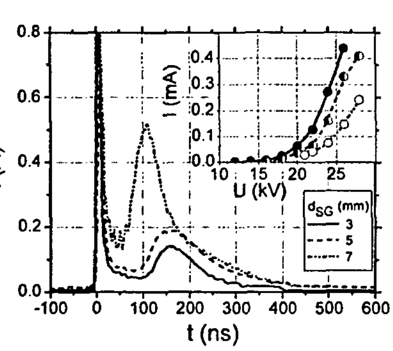

Fig.4. Discharge current waveforms for U = 28 kV and current-voltage characteristics for d_{SG} = 3, 5, 7 mm

For small gap lengths of the switch, the discharge current is relatively low (140 mA) and increases to more than 500 mA when increasing the gap length to 7 mm. However, the average current is higher for smaller gap lengths at constant applied voltage. This is due to the higher repetition frequency of the pulses for small gap length (1400 kHz, for d_{SG} = 3 mm and U = 24 kV) as compared to longer gap lengths (450 Hz, at d_{SG} = 7 mm) at the same voltage.

Fig. 5 shows the voltage waveforms on a long time scale for d_{SG} = 3 and 7 mm at 24 kV. For the small gap between the electrodes of the switch, a relatively low potential difference between them (~15 kV) is sufficient for breakdown, while the necessary voltage drop for the longer gap length is higher (22-23 kV). Since the time constant of the voltage decrease after the breakdown is the same, the repetition frequency of the pulses is higher for small gap lengths as compared to the frequency corresponding to longer gaps.

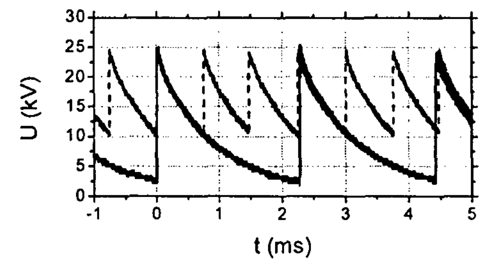

Fig. 5. Voltage waveforms for d_{SG} = 3, 7 mm and 24 kV

For small gap lengths, the corona high voltage electrode stays continuously at 10-11 kV, over which the pulses are superimposed. In these conditions, the lower values of the discharge current could be due to the lower amplitude of the voltage pulses.

4. Conclusions

The electrical characteristics of a pulsed multipoint-to-plane positive corona discharge were studied.

In the multipoint configuration the discharge current is higher as compared to the single point corona. Another advantage, especially for plasma-chemical applications, is the significantly higher active volume of the multipoint discharge: almost the entire cross section of the discharge chamber is filled with plasma.

Both the position and the number of pins used as high voltage electrode influence the characteristics of the discharge. The discharge current is higher as the number of pins is increased. Small distances between adjacent pins cause interactions between simultaneously propagating streamers due to changes in the electric field distribution near the pins, therefore the optimum spacing, where this interference effect ceases, was found to be 10 mm.

The functioning of the spark-gap switch determines the repetition frequency and the amplitude of the current pulses, at constant applied voltage, therefore the gap length of the switch is an important parameter in this configuration.

References

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